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Original Research Article

Effects of livestock grazing on key vegetation attributes of a remnant forest reserve: The case of Desa'a Forest in northern Ethiopia

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ABSTRACT

The study was conducted in Desa'a Forest with the objective of investigating livestock-forest interaction. This study also evaluated the grazing pressure on Desa'a Forests from livestock, the potential of forests biomass feed production and current livestock density relation to the sustainable stocking rate. Data on socio-economic and community perception about livestock-forest interaction were collected through structured questionnaire on 90 households. To determine the species composition, abundance, density and diversity of woody plants, using stratified random sampling, four transect lines were laid out in east, west, north and south direction. Accordingly, the results are representative of Desa'a Forest. In the study area, 90% of the respondents (81 households) entered their livestock into Desa'a Forest and only 10% of the respondents (9 households) did not use Desa'a Forest. A total of 63 woody plant species were identified in the study area. According to farmers and pastoralists' opinion, 49.15%, 15.25%, 28.81% and 6.79% of woody species were identified as highly palatable, palatable, less palatable and unpalatable respectively. The mean herbaceous biomass production in Desa'a Forest is 1255.86 kg/ha. The predicted mean annual browse biomass production was 3000.72 kg/ha. The potential stocking rates for Desa'a Forest were 68480.39 TLU/year obtained based on the amount of fodder available to the livestock in the forest. The available potential browsing unit per hectare in the centre, North-West direction and south-east direction was 1432.66 BU/ha, 665.83 BU/ha and 203.66 BU/ha, respectively. Only 5.65% of the total surveyed households practice forage development which are the key to overcome feed shortage and decrease the pressure from the forest.

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1. Introduction

Forests and woodlands are estimated to occupy 650 million ha or about 22% of the total land area of Africa, which corresponds to about 17% of the global forest cover (FAO, 2001). Firewood is the most important forest product and the main source of energy for most African households, accounting for 91% of all wood consumption. According to the FAO (2001), the forests of the East Africa region account for 21% of the forest area of Africa. However, the annual rate of deforestation in the region has increased from 0.7% during the period 1981–1990 (FAO, 1993) to 1% between of 1990–2000 (FAO, 2001). Ethiopia is one of the countries in this region with annual deforestation rate of 0.8% (FAO, 2001). The loss of forest cover in the country's highlands is not a recent phenomenon. However, the extent and intensity of forest loss to occur over the last hundred years has been severe.

The main agents of deforestation include agricultural expansion, grazing, consumption of firewood and charcoal, and forest fire. Poverty and rapid population growth are the main causes of deforestation. Owing to the severe deforestation, the recent data on forest resources of Ethiopia reported in (FAO, 2010) puts Ethiopia among countries with forest cover of 10–30%. According to this report Ethiopia's forest cover (FAO definition) is 12.2 million ha (11%). This process has a negative impact on the contribution of the forestry sector to the national income. Moreover, the degradation and depletion of the forest resource base has a major impact on other natural resource uses and sectors in the economy such as agriculture, and water resource, energy and biodiversity conservation. Such depletion of forest vegetation is particularly severe in the highlands of northern Ethiopia (Berhanu, 2000; Nyssen et al., 2004); almost all available land is under cultivation or used for pasture. Scattered, remnant forest stands of African pencil cedar (Juniperus procera Hochst. Ex Endl.) which are presumed to be the dominant natural forest type of the region, suggest that the highlands were once covered by these forests.

Forests and woodlots cover less than 1.6% of the area of Tigray (BoPED, 1995). Deforestation is due to cutting trees for fuel, timber and agricultural implements, and clearing forests to expand agricultural land. Forests, woodlots and grazing lands have been predominantly common-pool resources or open access resources in the region (Berhanu et al., 2000; Fujisawa, 2004), which resulted in wide-spread environmental problems, namely soil erosion, soil nutrient depletion, moisture stress, deforestation and overgrazing. The severe shortage of fuel wood made rural communities increasingly dependent on animal dung for fuel, which exaggerates the problem of declining soil fertility (Berhanu, 1998; Fitsum et al., 2002), but mainly contributes to an increased pressure on remnant forest stands. Although about 40% of the total land area is used for grazing (BoPED, 1995), shortage of feed sources is the major livestock production problem (Berhanu et al., 2000), which also increases pressure on remnant forest stands. On the other hand, Tigray is also known for its different efforts to address those problems. Major strategies of environmental rehabilitation concerning forests include establishment of exclosures, community woodlots and enforcement of grazing restrictions (Berhanu, 1998; Adhikari et al., 2004; Mekasha et al., 2014). Since 1991, the role of local communities in resource management has been increasing as the present government recognizes the importance of local participation in environmental and development projects. Nevertheless, little evidence exists about the nature of local level institutions and organization for resource management in Tigray and their effectiveness (Berhanu et al., 2000).

Desa'a Forest acts as a climate buffer between the Danakil deserts in the Afar region and the highlands of Tigray (Zenebe, 1999). Desa'a forest is one of the 59 National Forest Priority Areas (NFPAs) in the Ethiopia, which means that endangered endemic plant and animal species and genetic resources in general are protected, and that unique and representative habitats have to be conserved (TGE, 1994). Although Desa'a forest is a protected area, it is subject to illegal cutting and grazing, resulting in the reduction of forest cover, biodiversity loss and land degradation. Desa'a forest is a dry Afromontane forest that is located in a matrix of agriculture and strongly grazed Acacia shrub savannah (Janssens, 2009). It can be stated that this dry secondary forest is highly degraded (Zenebe, 1999). It has an average tree height of 3 m and is dominated by thorny shrubs and the trees Olea europaea subsp. cuspidata (Wall. Ex G.Don) Cif. (or African Olive) and African pencil cedar, while other dominant species are Carissa edulis Vahl, Dodonaea viscosa var. angustifolia (L.f.), Benth and Maytenus obscura (A.Rich.), and Cufod (Janssens, 2009). Natural regeneration is rather low like in most Tigray forests (Janssens, 2009).

Grazing is still practiced in traditional forest management systems in many parts of the world. In mountain environments, where agricultural activities are constrained by climate, animal husbandry is one of the livelihood options available to many farmers. In the Mediterranean region of North Africa, forest grazing is still a popular tradition (Karmouni, 1997). Forest grazing is also widely practiced in Bhutan and Himalayan coniferous forests (Roder et al., 2002). According to Mekasha et al. (2014), the multipurpose utilization of forest resources including forest grazing has a long tradition in the Swiss Alps. It is also a very common practice in the montane forests of Ethiopia. Although Desa'a Forest is a protected area, it is subject to grazing, resulting in the reduction of forest cover, biodiversity loss and land degradation. Livestock grazing is a very important element of household income in many communities in Tigray. This is also true in case of communities around Desa'a Forests as their livelihoods depend on livestock and forests. Therefore, the overall objective of this study was to assess the effect of livestock and remnant montane forest reserve interactions at Desa'a Forest in northern Ethiopia. More specifically, the paper aims to:

1 Assess the socio-economic characteristics and perception of the community on forest and livestock interaction.
2 Quantify the current magnitude of grazing pressure on key vegetation attributes in Desa'a Forest.
3 Determine actual and potential the above-ground biomass production of feed in the study area.
4 Explore the potential and mechanism of introducing fodder trees in the farming system to alleviate grazing pressure inside the forest.

2. Material and methods

2.1. Site description

The study was carried out in 'Dessa'a Protected Area' (130 20 and 140 10′ North latitudes and between 390 32′ and 390 55′ East longitude) located in the cross border between Tigrai and Afar region and a considerable part of the area falls within the former region (Fig. 1). The forest part located within Tigrai region is bordered by Saesie Tsaeda Emba, Atsbi Wonberta and Enderta. The part of the protected area falling in Afar Region is bordered by Aba'ala, Berahle, and Dalol.

2.2. Methodology

2.2.1. Household survey

The household survey was carried out in three selected villages (kushets[1]) around the Desa'a Forests. Two of the kushets were from Tigray region (Atsbi wereda[2]) and one was from Afar region (Berhale wereda). Accordingly, Lugda from Kalisha emini, Enguleta from Era Tabias[3] (Atsbi wereda) and Kessurtu from Ala Tabia (Berhale wereda) were selected. The villages were selected purposefully, due to their closeness to the forest and dependency of the community on the forest for their livestock.

Secondary information pertinent to the study areas was collected from previous studies, organizations (Atsbi and Berhale Wereda burea of Agriculture) and other sources. Furthermore, information was gathered through interviewing individuals, groups, key informants and personal observation. Before conducting the formal questionnaire survey, the questionnaire was tested in some households and necessary modification was made. The purpose of pre-testing was to identify any ambiguity or errors in questions. Interviews were made with the livestock owners including farmers and pastoralists. The Interviews were made with the family head member as far as possible and in the absence of family head the interviews were made with representative and knowledgeable member of the household. Trained enumerators assisted in collecting the data. We consulted the willingness of the participants to make the results of their interviews available to the public.

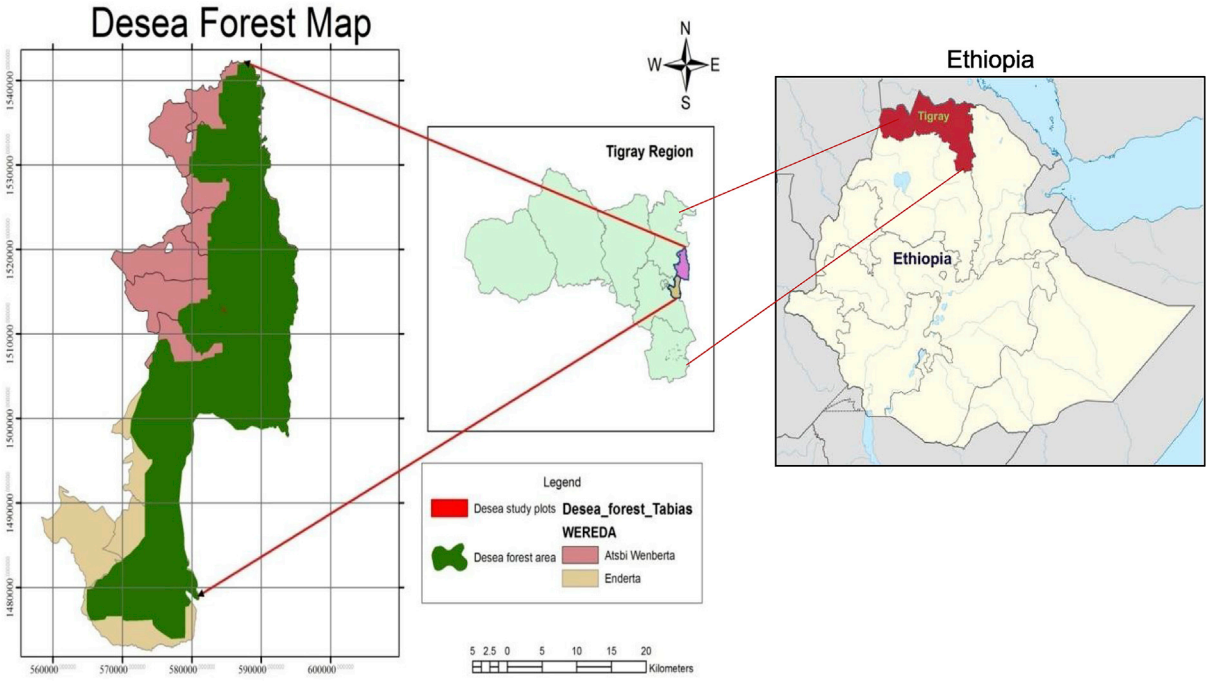

Fig. 1. Map of the study area.

[1] Kushet is the least administrative hierarchy below Tabia.
[2] A wereda is a local government unit higher than the kebele, the lowest tier of government.
[3] Tabia is the lowest administrative hierarchy below Woreda.

Table 1
Criteria used for separating wealth rank in the study area.

Wealth rank	Livestock	Land holding
Low income	Having 0-1ox driven and less than three cow	Having from 0 to 0.25ha cultivated farm land)
Medium income	Having 2-3ox drive and some cow 3-5	Having >0.25ha and <0.75ha
High income	Having above 4 and more ox drive and above 6 cows	Having one and above ha

A stratified random sampling technique was employed to select the sample respondents from each village based on the wealth status of the household lived in the selected kushet. Firstly, five local key informants who are knowledgeable regarding the sample villages were selected through the assistance of Tabia leaders and local development agents from each kushet. Secondly, local terms for wealth, village and household were elicited and defined with local informants according to the wealth of each household. The households were separated based on the livestock and land holding availability. Thirdly, with the help of criteria settled by the key informants, each household was grouped into three group strata as low, medium and high incomes and the list of household heads under each wealth category was obtained (Table 1). Lastly, a random sampling technique was employed to select the sample of households. A total of 90 respondents from the selected Tabias was interviewed, where 60 respondents were from Tigrai and 30 respondents were from the Afar region.

2.2.2. Field vegetation measurements

Using stratified random sampling, four transect lines were laid out in east, west, north and south direction, so that results are representative of Desa'a Forest. To determine the species composition, abundance, density and diversity of woody plants, using stratified random sampling four transect lines were laid out in east, west, north and south direction, so that results are representative of Desa'a Forest. A total of 37 plots (14800 m^2) were taken at every 100 m drop along each line in the forest. Each plot of 20 $\times$ 20 m in each of the sample site was taken as an experiment unit for data analysis.

Height was measured by tape meter. Diameters at stump height (DSH) and diameter at breast height (DBH) were measured by diameter tape. DSH was measured at 30 cm from ground. DBH was measured at 130 cm from the ground. In each plot, for woody vegetations (trees/shrubs) within (400 m^2) plot, only live woody plant species were recorded and identified. Based upon the opinion of the pastoralists, the species were divided into highly palatable, palatable, less palatable and unpalatable.

The desirability and palatability of each species was recorded based on the discussion with the livestock owners (farmers) and by giving attention to the woody plants' sensitivity to grazing, abundance and preferences of the livestock as a feed resource.

During the interview questionnaire, farmers were asked about which of the indigenous trees found in the forest are browsed by their livestock and the priority was given to these tree species. The potential fodder yield of browse species was then estimated by entering the diameter value in the equation developed by Petmak (1983) as given below:

$$\log w = 2.24 \log DT\text{-}1.5$$

Where;

w = leaf yield in kilograms of dry weight, and
DT = trunk diameter (cm) at 130 cm height, and

for the leaf yield of shrub the allometric equation is:

$$\text{Log } w = 2.62 \log DS - 2.45$$

where; DS = the stem diameter (cm) at 30 cm height
Within the main plot of 400 m^2 used for woody species, five quadrats of 1 m $\times$ 1 m (1 m^2) were setup from the centre, and the rest from each corner to be the representative of the whole plot. These plots were used to collect data on biomass of herbaceous species and the mean of five quadrats was used in the analysis.

2.2.3. Determining browsing capacity, browsing units and tree equivalents of montane reserve forest

Browsing capacity, browsing capacity and tree equivalents of theforest vegetation were determined using the Point Centered Quarter *(PCQ)* method. The data was collected at three sites in the forest. One was at high altitude (2530 masl) at *center* of the forest. The second one was at lower altitude in the *North-west* (2330 masl) direction from the centre. And the third one was at the lower altitude (2330masl) in the *South-east* direction from the centre.

A BU is defined by Trollope et al. (1990) as a tree or shrub that is acceptable to goats and is either 1.5 m in height or has browse within 1.5 m of ground level. Then browsing units are calculated by multiplying the number of bushes in each height class by the median for each height class up to a height of 1.5 m. Thereafter the number of bushes are multiplied by a factor = 1.5 m for the remainder of the height classes. The sum of the products is divided by 1.5 m to convert them to browsing units.

The number of *Tree Equivalents* per hectare which represents the phytomass of bush in all height classes was calculated in the sample site. A tree equivalent is defined as a tree or shrub that is 1.5 m high and represents an index of the phytomass of trees and shrubs present in the plant community that are being sampled.

The tree equivalents are calculated by multiplying the number of bushes in each height class by the median for each height class. The sum of the products is divided by 1,5 m to convert them to tree equivalents.

The browsing capacity was estimated based on empirical research and 2000 browsing units can produce sufficient browse to support one mature goat (SSU) per year. Therefore, using the results derived from the data, the browsing capacity is estimated using the following formula:

Browsing Capacity = 2000/ Browsing Unit

2.2.4. Determination of sustainable livestock stocking rates

The livestock holdings of the user groups were converted to tropical livestock units, as an indicator of grazing pressure. According to Weber and Jelsch (2000), one tropical livestock unit (TLU) is equivalent to 250 kg live weight, which is approximately one head of cattle, or 10 sheep, 11 goats and 0.7 camels. It is assumed that horses and donkeys are the equivalent of a head of cattle.

Based on the fodder production capacity of the forests and the number of livestock units grazing in the forests, the stocking rate for Desa'a Forest was determined as follows (Amante, 2005):

$$\text{Stocking rate} = \frac{\text{ADM (kg) per forest area}}{Dc{*}365\ days}$$

Where,

ADM = available dry matter.
DC = daily consumption by one tropical livestock unit, which is 6.25 kg of dry matter/day (Weber and Jelsch, 2000).

This study has accounted for the environmental conditions which are not equally accessible when estimating the stocking rate. The rate for Desa'a Forest was determined based on the fodder production capacity of the forests and the number of livestock units grazing in the forests. Available dry matter was determined based on the 'take 70% and leave 30% method' (Petmak, 1983); 70% of the total biomass produced per hectare and year will be available to livestock with the rest left on the pasture to avoid overgrazing.

2.2.5. Data analysis

Descriptive statistics such as mean, percentages range and standard deviations were used for data survey. In the case of the woody vegetation, a total of 37 plots (14800 m^2) was taken. Each plot of 20 × 20 m at each of the sample site was taken as an experiment unit for data analysis. Woody species composition for each species was calculated by dividing the number of each species by the total number of all species and density of woody species was defined as the number per area of each species. All data analysis were performed using SPSS version 16 (SPSS 2007). One-way ANOVA was used .

3. Results

3.1. Household survey

3.1.1. Socio economic characteristics of the study area

The average family size in the study area was 6 persons/household with a range of 1–14 (Table 2). This figure is comparable to that reported for the rural areas of Afar region (6) (CSA, 1996) and Kereyu pastoralists (6.17) (Abule, 2005). The age of respondents ranged between 20 and 75 years. The average age in the study area was 42.26 years old. There were 58 (64.4%) male and 32 (35.6%) female respondents in the household survey.

3.1.2. Livestock ownership

Livestock production is known to be the main production system for both pastoralists and agro Pastoralists (mixed farming) since livestock have been the main assets especially for the pastoralists in the study area upon which the livelihood of the pastoralists depend. The livestock species reared in the study area were included cattle, camels, goats, sheep and

Table 2
Socio-economic and demographic characteristics of the respondent household (N = 90) (Tigrai = 60; Afar = 30).

Socio-economic information	Frequency (%)	
sex	Male	58(64.4)
	Female	32(35.6)
Age	20–30	24(26.7)
	31–50	41(45.5)
	51–65	20(22.22)
	>65	5(5.6)
Family size	1–5	41(45.6)
	6–10	45(50)
	11–15	4(4.4)
Level of education	Illiterate	63(70)
	Basic education	8(8.9)
	Grade 1-4	19(21.1)
Farming activity	Livestock production	30(33.3)
	Mixed farming	60(66.7)

donkeys. Pastoralists reared dominantly cattle, camels and goats; while agro-pastoralists reared dominantly cattle in the study area.

The result of the household survey revealed that the mean livestock holding per household was 17.67TLU, 7.04TLU and 7.31 TLU in Kessurtu, Lugda and Enguleta Kushets, respectively. The overall mean of livestock holding per household for the study area was 10.68 TLU (Table 3). In the study area, cattle were the dominant species and accounted for 51.30%, 77.08% and 71.06% of the herd composition of Kessurtu, Lugda and Enguleta, respectively.

3.1.3. Feed resources in the study area

Under extensive pastoral production system, livestock production depends entirely on exploiting extensive rangeland resources that possess natural grasses and browse species. Similarly, the information obtained from 90% of the respondents in the mixed farming system and pastoralists during interview indicated that, the major feed sources available for the entire livestock in the study area are natural grasses, bushes, shrubs, and trees from Desa'a Forest. The availability and use of these resources vary with seasons.

According to the respondents from the pastoralist area (33.3%) the feed resources available to livestock during the main rainy season were grasses, and most preferred bushes and shrubs. During dry season livestock utilize mainly browse resources such as trees, bushes and shrubs and they supplement their livestock by buying either hay or straw from neighboring tabias of Tigray, if critical feed shortage happened. The available feed sources for livestock for the mixed farming system (66.7%) were grass and browse species from Desa'a Forest during wet season. During dry season for the Lugda Kushet (33.3%), they use browse species from the forest, conserved hay and straw. For 33.3% of the respondent from the Enguleta Kushet the available feed resources during dry season were browse species, conserved hay, straw and cactus. About 66.7% of the respondents in mixed farming system use crop aftermath from October to December.

Feed shortage in the study area happened according to most of the respondents (55%) from March to June. The pastoralists (33.3%) supplement their animals by lopping leaves and twigs and harvesting seeds of browsing plants during critical feed shortage time, and in the mixed farming system (66.7%) in addition to browse species, they supplement their livestock from conserved hay and straw during critical feed shortage period. According to 66.7% of the sampled households in the mixed farming system, measures taken to solve the problem of feed shortage during dry periods were lopping the leaves and twigs of woody plants, and using conserved hay and straw. The measures taken to solve the problem of feed shortage by pastoralists (33.3%) were lopping the leaves and twigs of woody plant, migrating (to where there is rain and grass) and destocking.

3.1.4. Desa'a Forest as a source of feed for livestock and ways of utilization by the community

The pastoralists (Kessurtu Kushet) totally depended on Desa'a Forest for their livestock feed. They used the grass and browse species inside the forest for the whole year. For 9 months they stayed inside Gare (temporary residing site for livestock). Based on the time they stayed in the forest, there was significance differences ($p < 0.05$) among the three study area. As they stayed in the forest for more time the effect of grazing and browsing increased. In the study area 90% (81) of the respondent entered their livestock into Desa'a Forest and only 10%(9) did not use Desa'a Forest as sources of feed for their

Table 3
Average ± SE (standard error) livestock holding per house hold for the study area.

Kushets(village) Type of livestock					
cattle		goat	camel	sheep	donkey
Kessurtu	9.06 ± 1.202	3.24 ± 0.292	3.85 ± 0.483	0.74 ± 0.233	0.77 ± 0.061
Lugda	5.43 ± 0.634	0.55 ± 0.136	0.11 ± 0.11	0.02 ± 0.021	0.93 ± 0.069
Enguleta	5.2 ± 0.617	0.88 ± 0.236	0 ± 0	0.04 ± 0.03	1.19 ± 0.089

TLU equivalent Goat and sheep = 0.13, Cattle = 1, Donkey = 0.7 and camel = 1.1.

livestock. On average, the livestock used Desa'a Forest as a source of feed for 8 months. From the respondents, 38.9% (35) used Desa'a Forest as sources of feed for their livestock for the whole year and 10% (9) did not enter their livestock to the forest. Those 10% who did not enter their livestock into the forest used grass by cut and carry system from the forest. More than 65.6% used the forest for more than 8 months. The results indicate the dependence of the respondents on the forest for their livestock feed.

Woody plants are important resources in Desa'a Forest. They play an important role in pastoral and mixed farming systems due to their multiple uses they provide to human being. The present survey results exhibited that, 90% of the inhabitants of both study areas use woody plants for different purposes, the primary being as a source of livestock feed. They are considered as the sole feed source for browsers during the dry period. Grazing inside the forest was divided into two, for plough-oxen and for other livestock. In Era and Kalisha, *Tabias* there are temporary forest exclosures (*Den-Huzaeti*) i.e. part of the forest is seasonally closed for grazing of plough-oxen from June to the end of September. In Era tabia alone there were seven exclosure areas which are used for plough-oxen grazing. It will be opened for grazing after September. The local people govern their grazing area through their local bylaws (*Srit*). The plough-oxen grazing area is particularly protected by guards elected by the local community, from the entrance of any other livestock. Those members of the community who have plough-oxen pay five Birr per plough-oxen. The money was collected by Tabias chairman and paid to the guards elected by the community.

3.1.5. The perception of farmers and pastoralists on forest −livestock interaction

The survey results showed that the respondents understand the interaction between forest and livestock grazing inside the forest. About 90% of the respondents use the forest primarily for livestock grazing. The livestock get grass and browse species from the forest and use the forest as shade to protect the livestock from direct sun light. On the other hand livestock also add their manure to the forest which is adding nutrient to the forest.

The decreasing species from the forest according to the respondents were 'Amdug', 'Armedi', and Diospyros abyssinica and mentioned by 59, 54, and 30 respondents, respectively. The inventory data also shows that the species mentioned by the farmers has less than 1% abundance. The reasons for the reduction of these species as mentioned by 65% the respondents were over browsing and grazing during drought period, lopping, deforestation and livestock damage. Especially Amdug was one of the species that decreased from Desa'a Forest from time to time. According to respondents, the reasons for the reduction of these species inside the forest were during dry season when they either directly browsed or cut and given to livestock. These indicate that there was high browsing effect on such species during dry period.

Only 45.6% believed that livestock cause damage to the forest and 54.4 of the respondents say livestock have no impact on the forest. The major damages were browsing damage and trampling by camel and cattle. Defoliation is the most widely recognized mechanism through which livestock affect vegetation. It has been argued that intense repeated defoliation during the rainy season will lead to the prevalence of short cycle species with heterogeneous germination patterns. Prolonged heavy grazing undoubtedly contributes to the disappearance of palatable species and the subsequent dominance by other, less palatable, herbaceous plants or bushes. In the study area 58% of the respondents believed that the current stocking rate did not cause pressure to the forest. Those respondents, who believed that there was no damage by livestock, their reason was that grass and trees were regenerating after browse or grazing.

3.2. Vegetation measurements

3.2.1. Species richness and abundance

A total of 63 woody plant species were identified in the study area. According to the opinion of farmers and pastoralists in the study area 49.15%, 15.25%, 28.81%, and 6.79% of woody species were identified as highly palatable, palatable, less palatable and unpalatable, respectively.

The five most abundant species in the area were *Cadia purpurea*, *Tarchonanthus camphoratus*, *Dodonaea viscosa*, *Olea europaea*, and *Maytenus obscura*. *Cadia purpurea* is the first most abundant tree in the Dess'a forest but it was one of the unpalatable species for livestock. *Tarchonanthus camphoratus*, *Dodonaea viscosa*, *Olea europaea,* and *Maytenus obscura* are palatable and available for livestock. The abundance of highly palatable species were *Diospyros abyssinica* 9(0.23%), *Maytenus undata* 3(0.07%), *Astralogus astropiluls* 1(0.02%), and Armedi 1(0.02%). They have low abundance and this is due to the browsing effects in the area.

3.2.2. Species density and Frequency

A total of 3685 individual woody species were encountered in Dess'a forest during the inventory. A total density of woody species of the area was 2605 individuals per hectare. *Cadia purpurea* was the densest species in the forest with 735 per hectare. Seven woody species with the highest density were *Cadia purpurea* (735 Ind/ha), *Tarchonanthus camphorates* (334.45 ind./ha) , *Dodonaea viscose* (200 ind./ha) , *Olea europaea* (157.43ind./ha), *Maytenus obscura* (131.75ind./ha) , *Combretum aculeatum* (127.02 ind./ha), and *Rhus vulgaris* (115 ind./ha). Seven species have more than 100 individuals per hectare.

The ten most frequent species in the forest were Rhus vulgaris 45.94% (17), *Olea europaea* 43.24% (16), *Cadia purpurea* 43.24% (16), *Maytenus obscura* 35.13% (13), *Combretum aculeatum* 35.13% (13), *Tarchonanthus camphoratus* 29.72% (11), *Carissa edulis* 29.72% (11), *Rhus glutinosa* 29.72% (11), Grewia villosa 27.02% (10), and *Juniperus procera* 27.02% (10). The most frequent

species in plot, Rhus vulgaris has less than 5% abundance. Frequency reflects the pattern of distribution and gives an approximate indication of heterogeneity of a stand.

3.2.3. Basal area and importance value index

Basal area (BA) of all woody plants was 273.351 m^2 per hectare for the Desa'a. The highest basal area proportion for the woody plants was for *Olea europaea*. The following species made the largest contribution to the basal area: *Olea* europaea (30.83%), *Tarchonanthus camphoratus* (10.65%), *Acacia etbaica* (10.12%), Cadia *purpurea* (9.9%), *Juniperus procera* (4.61%), and Acacia asak (4.13%) (Table 4).

According to the important value index Cadia *purpurea* (43.64), *Olea* europaea (42.39), *Tarchonanthus camphorates* (27.28), *Acacia etbaica* (14.53), *Dodonaea viscose* (13.85), Rhus vulgaris (12.47), *Juniperus procera* (10.42), *Combretum aculeatum* (10.35), and *Maytenus obscura* (10.24) were the first nine most important dominant species in Desa'a Forest.

3.2.4. Diversity

The diversity index for the woody species found in Desa'a Forest was calculated and the summary was presented below (Table 5).

The Shannon diversity index of Desa'a Forest was found to be 2.75 reflecting good diversity. The 63 species found in the area were evenly distributed with Shannon evenness value of 0.66. According to Kent and Cooker (1992), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5, and low Shannon evenness is an indication of the existence of unbalanced distribution of the individuals of species encountered at a given study areas. However, it can be said that the area with good diversity and with more or less even representation of individuals of all species encountered in the study area.

3.2.5. Height

The average heights of the trees in the forest were 2.07 m. Most of the highly palatable woody species in the forest have less than 2 m. The average height of some of highly palatable woody species in the forest were *Grewia villosa* (1.13 m), *Grewa kakothamnos* (1.41 m), *Eculea racemosa* (1.86), *Rhus glutinosa* (1.61 m), and *Clerodendrum myriodes* (1.48 m). About 59% of woody species found in Desa'a Forest were found in the height class less than 2 m (Fig. 2). Height has an important habitat connotation. For instance, only trees and shrubs below a certain height can be browsed by various livestock (Alemayehu, 2005). Since the majority of the species have height less than 2 m, they can be browsed by livestock using Desa'a Forest as a source of their feed. The effect of browsing in Desa'a Forest was reflected in the stunted growth of palatable species. Most of the species were dwarf. This was due to the repeated browsing on the trees and shrubs.

3.2.6. Herbaceous biomass

The herbaceous biomass production in Desa'a Forest was ranging from 394.36 kg/ha to 3662.84 kg/ha. The mean biomass production of the forest is 1255.865 kg/ha (Table 6).

3.2.7. Potential and current stocking rates

The potential stocking rates for the Desa'a Forest were obtained based on the amount of fodder available to the livestock in the forests and the annual consumption of a livestock unit (Table 7).

The current stocking rate in Desa'a Forest is at its maximum limit, which implies the need to control any further increases to avoid the effects of over grazing and over browsing. The herbaceous biomass produced in the area was low. The shortage was filled by browse biomass in the forest. The pressure from livestock in the forest was at its maximum limit. These indicate that high pressure on browse species is due to low herbaceous biomass production. That is why some of the highly palatable species were decreasing from Desa'a Forest.

3.2.8. Browsing units, tree equivalent and browsing capacity determination

The available browsing unit per hectare in the North-West direction was 665.83 BU/ha. The BU/ha found around the center was and greater than both North-west and South−east direction. The BU's/ha for these sites was 1432.667 BU/ha (Table 8). The BU's/ha for the south-east direction was less than the other two sitesin which 203.66 BU/ha was found. The central site provides about twice the potential of BU's/ha than the forest found at North-west direction and 7 times than those found at south-west direction.

The available Tree equivalent for centre, North-west and South-east were 1849.333 TE/ha, 851.1667 TE/ha, and 337.1667 TE/ha, respectively. The highest Tree equivalent was found at the centre of the forest.

Potential browsing capacity for west direction = 2000/ 665.8333 = 3.003755 ha/ssu

Potential browsing capacity for centre (high altitude) = 2000/ 1432.667 = 1.395998 ha/ssu

Potential browsing capacity for south direction = 2000/ 203.6667 = 9.819967 ha/ssu.

The browsing capacity determined for the three sites were 3.003755 ha/ssu, 1.39 ha/ssu, and 9.82 ha/ssu for north-west direction, centre and south-east direction, respectively. In the center of the forest, where there are more BU's/ha, small areas are needed to support SSU per year. That was only 1.39 ha needed to support one SSU per year, whereas in the south east

Table 4
Importance value indices for woody species (RD-relative Density, RF- Relative Frequency, RDO- Relative Dominance, IVI- Importance Value Index).

No	Scientific name	Local name	RD	RF	RDO	IVI
1	Cadia purpurea	Silien	28.21	5.52	9.91	43.64
2	Olea europaea	Awlie	6.04	5.52	30.83	42.39
3	*Tarchonanthus camphoratus Houtt. ex DC.*	Ebuk	12.83	3.79	10.66	27.29
4	Acacia etbaica Schweinf.	Seraw	0.95	3.45	10.13	14.54
5	*Dodonaea viscosa* var. *angustifolia* (L.f.) Benth.	Tahses	7.67	2.76	3.42	13.85
6	Rhus vulgaris Meikle	Atam	4.43	5.86	2.18	12.47
7	Juniperus procera Hochst. ex Endl.	Sareda	2.35	3.44	4.61	10.42
8	*Combretum aculeatum* Vent.	Korenet	4.87	4.48	0.99	10.36
9	Maytenus obscura (A.Rich.) Cufod	Atat	5.05	4.48	0.71	10.25
10	Dracaneae ombet	Ajera	0.57	1.72	6.98	9.27
11	Carissa edulis Vahl	Egam	2.90	3.79	0.52	7.21
12	Acacia asak	Acacia asak	1.24	1.72	4.14	7.10
13	Rhus glutinosa Hochst. ex A.Rich.	Kalalanko	2.69	3.79	0.26	6.75
14	Grewia villosa	Dintu	2.69	3.45	0.28	6.42
15	Mekar[b]	Mekar	1.86	2.41	2.14	6.42
16	Grewia kakothamnos K.Schum.	Kertemtemo	3.73	1.72	0.65	6.11
17	Clerodendrum myrioides	Shewha	1.94	2.41	0.11	4.47
18	*Euclea racemosa* Murr.	Kilewu	0.80	3.10	0.28	4.19
19	Lepisanthes senegalensis	salaha	0.700	2.41	0.92	4.03
20	Acokanthera schimperi (A.DC.) Benth. & Hook.f. ex Schweinf.	Mebtie	0.31	1.72	1.89	3.92
21	Acacia mellifera	Acacia mellifera	1.37	1.03	1.27	3.68
22	Acacia polycantha	Gomoro	0.36	2.07	0.74	3.17
23	Tarare[b]	Tarare	0.02	0.34	2.22	2.59
24	*Calpurnia aurea* (Lam.) Benth.	Hitsawuts	0.70	1.38	0.40	2.48
25	*Dovyalis verrucosa* Warb.	Meigabu	0.31	2.07	0.03	2.41
26	Osyris quadripartita Salzm. ex Decne.	Karets	0.26	2.07	0.07	2.40
27	*Acacia abyssinica* Hochst. ex Benth.	Chea	0.26	1.38	0.27	1.91
28	Girardiria diversifolia	Dabiya	0.700	1.03	0.17	1.90
29	Alaitu[a]	Alaitu	0.26	1.38	0.20	1.84
30	Leucas abyssinica (Benth.)Brig.	Swa karni	0.31	1.38	0.05	1.74
31	*Clutia abyssinica* Jaub. & Spach	Tush balalti	0.49	1.03	0.03	1.56
32	Psydrax schimperiana (A.Rich.) Bridson	Tsehag	0.16	1.03	0.28	1.47
33	Myrsine africana L.	Tsatse	0.16	1.03	0.17	1.36
34	Meriandra dianthera (Roth ex Roem & Schult.) Briq.	Meseghu	0.23	1.03	0.01	1.33
35	Abutilon pannosum	Buwak	0.47	0.69	0.17	1.32
36	Diospyros abyssinica (Hiern) F.White	Tselimo	0.23	0.69	0.30	1.22
37	Yalu'i[a]	Yalu'i	0.03	0.34	0.70	1.07
38	Alaku[b]	Alaku	0.03	1.03	0	1.06
39	Armed[b]	Armed	0.03	1.03	0	1.06
40	Sheko[b]	Sheko	0.03	1.03	0	1.06
41	Balanites aegyptiaca	Balaaegy	0.16	0.69	0.15	0.99
43	Bobohoo[b]	Bobohoo	0.10	0.69	0.01	0.81
44	Molesha[a]	Molesha	0.08	0.69	0.02	0.79
45	Awha[a]	Awha	0.08	0.34	0.33	0.76
46	Astralogus astropilosulus	Tetem agagen	0.03	0.69	0	0.72
47	Adhode[b]	Adohade	0.03	0.34	0.30	0.68
48	Dogho[b]	Dogho	0.03	0.34	0.26	0.64
49	Dobera glabra	Garsa	0.03	0.34	0.09	0.47
50	Cyphostemma adenocaule (Steud.exA.Rich.)	Mrkus zebeie	0.08	0.34	0.01	0.44
51	Maytenus undata (Thunb.) Blakelock	Tsamo	0.08	0.34	0.01	0.43
52	*Rhus natalensis Bernh.exc.Krauss*	Mashela	0.03	0.34	0.03	0.40
54	Grewia erythrea	Hidaiatto	0.05	0.34	0.002	0.40
55	Tebeb[a]	Tebeb	0.05	0.34	0.001	0.40
56	Grewia bicolor Juss.	Reway	0.03	0.34	0.006	0.38
57	Withania somnifera	Agol	0.03	0.34	0.002	0.37
58	Jasminum abyssinicum	Habi tselim	0.03	0.34	0.001	0.37
59	Rumex nervosus	Hohot	0.03	0.34	0.001	0.37
60	Solanum incum	Engule	0.03	0.34	0	0.37
61	Aloe berhana	Ere	0.03	0.34	0	0.37
62	Har-har[b]	Har-har	0.03	0.34	0	0.37
63	Taritu[b]	Taritu	0.03	0.34	0	0.37
total			100	100	100	300

[a] local name (Afar).
[b] local name (Tigrigna).

direction 9.82 ha was needed to support one mature goat (SSU) per year. The BC for the three sites was significantly different ($p \leq 0.05$).The average BC for the forest was 4.73ha/ssu. So that, the forest in general can support 18962 ssu/year.

Table 5
Summary of diversity index for Desa'a Forest.

Diversity index	value
Number of individuals	3856
Species richness	63
Shannon's index	2.755
Simpson's equality index	0.134
Shannon evenness	0.66

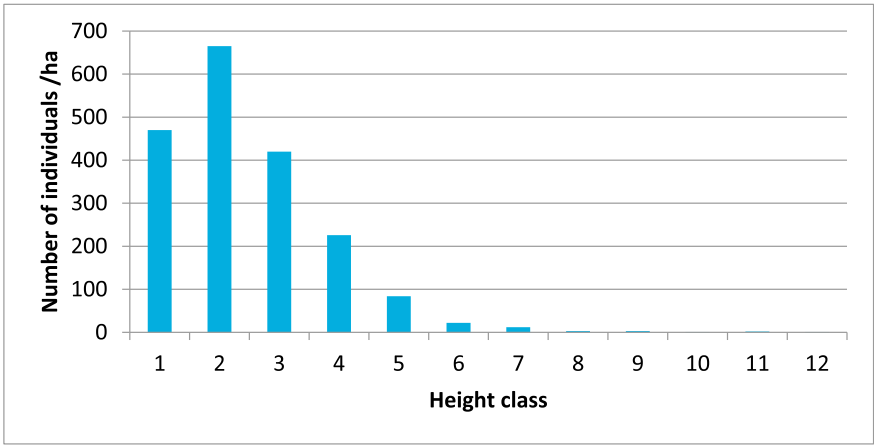

Fig. 2. Frequency distribution of height classes (m) for wood species at Desa'a Forest.
Height class 1<1m, 2=1-2m, 3=2-3m, 4=3-4m, 5=4-5m, 6=5-6m, 7=6-7m, 8=7-8m, 9=8-9m, 10=9-10m, 11=10-11m, 12=11-12m.

Table 6
Mean herbaceous biomass production (Kg/ha) from Desa'a Forest.

	Kg/ha
Min	394.36
Max	3662.84
Mean	1255.865
Standard error mean	3121.9

Table 7
Potential and current stocking rates in tropical livestock unit (TLU) for 365 days.

Description	value
Potential stocking (TLU)	68480.39
Current stocking (TLU)	68722.402
Ratio of current/potential stocking (%)	100.35

Table 8
Available Bu, TE and BC determined for the three sites.

sites	BU	TE	BC
Center	1432.67[a]	1849.33[a]	1.39[a]
North-west	665.83[b]	851.17[b]	3.003[b]
South-east	203.67[c]	337.17[c]	9.82[c]

BU=Browsing unit, TE = Tree equivalent and BC = browsing capacity.
Means not connected by the same letters are significantly different.
The BU's for the three sites were significantly different ($p < 0.05$).

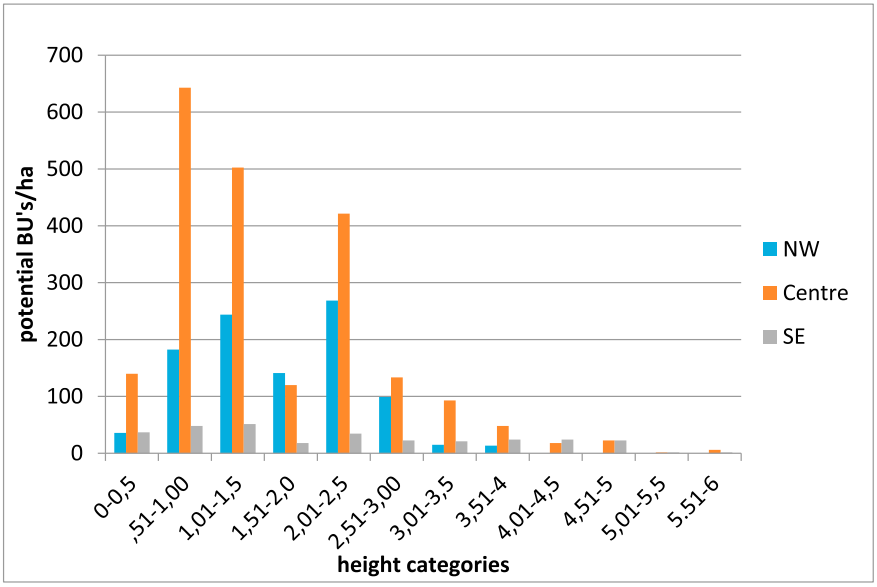

Fig. 3. The number potential BU's/ha contributed by plants in the 0.5 m height categories in the three sampling sites in Dessa'a Forest.

The high contribution to potential BU's/ha of woody plants in the height categories<1.5 m in the centre reflects the abundance of shorter vegetation that is easily available for goat (SSU) since they are able to browse within 1.5 m height (Fig. 3).

3.2.9. Assessment of agro forestry in the study area

The survey study results revealed that 55.6% of the respondents had trees inside their home compound or on their farm land and 44.4% had no trees in their farm or home compound. The available tree species were *Olea europaea*, *Abutilon pannosum*, *Calpurnia aurea*, Cactus, *Acacia etbaica*, *Carissa edulis*, *Juniperus procera*, *Rhus vulgaris*, Eculptus species, *Acacia saligna*, Grewia kakothamno, Psydrax schimperiana, Tarchonanthus camphoratus, *Sesbania sesban,* and Elephant grass.

The households that have trees or shrubs in their home compound 98% of them uses for livestock feed and only 2% of the respondents do not use the trees for their livestock. From the available tree or shrub, 31.1% of the house hold planted by themselves and the rest existed naturally. The average of households planted trees in their compound were 31.1% and 68.9% do not practice any planting activities. The plant species planted by farmers were Cactus, Eucalyptus species, Sesbania sesban, and Elephant grass. The plant species planted by farmers were used for livestock feed, house construction, fence and human food. Especially Cactus gives a multi-purpose uses for the farmers. It was used as food for human, feed for livestock and serves as live fence.

There are many different ways of forage development techniques to be adopted to cope up with feed scarcity periods by small holder farmers even though the extent of using these techniques by farmers of our country is quite minimal. It was proved that there were FTC established decades before in the study sites with the objective of disseminating Seeds and technology to the farmers. Total surveyed farmers of the study sites showed that 5.6% of the farmers ever used forage development techniques before and those farmers using these techniques were from Enguleta Kushet. Lugda and Kessurtu Kushets did not yet use improved forage.

The survey results revealed that there was no practice of zero grazing in the study area. About 40% of the household do not use improved forages because they have free access to Desa'a Forests. 33.33% (30) of the surveyed households do not use improved forages either because they have the limitation of introduction through awareness or they have lack of extension agents' advice. Generally 94.4% of the households' respondents do not use improved feeds for their livestock. A quite considerable number of households of 22.22% (17) and 35.55% (32) did not use improved forage due to lack of access to seed and shortage of water, respectively, while 20 households which are 22.22% do not use improved forage due to lack of permanent settlement or migration.

The major constraints of forages development voiced in Dessa'a were free access to forest, lack of permanent settlement (migration), lack of awareness, seed, water, and land shortages. Lack of awareness and difficulties of obtaining seeds may be overcome by extension and seed distribution. The shortage of land is likely to become increasingly serious as the population continuous to grow. There will need to be an intensification of agricultural production to overcome the problems of land shortages; this intensification is likely to require forages and farmers will therefore need to be encouraged to plant forages, despite the current shortages of land. Although these forages will take up some land, they more than compensate by raising overall farm productivity or have to be incorporated within crops.

Despite the apparent potential of forage technologies, farmers' adoption has often been poor. Often the problem is not lack of supplying new technologies but the poor uptake of existing technologies. Lack of awareness of forages often resulting from poor extension, may act as a constraint to adoption.

4. Discussion

The respondents in the study area keep more than one livestock species. These consist of goats and camels which are mainly browsers and sheep and cattle which are mainly grazers. The view of the pastoralists suggested that, mixed stocking with two or more species of different feeding, ranging, production, disease and drought resistance, and reproductive characteristics maximizes yield and provides long-term security for herder by using all available resources. This agrees with the reports from the other pastoral areas of Ethiopia and the East African countries (Swift et al., 1996). In accordance with the studies of Scoones (1995) and Nigatu et al. (2004), mixed stocking with two or more species having different feeding habits would enable better use of resources and has often been more profitable.

According to the respondents, from the pastoralists only 3 respondents conserve hay for dry season. The majority (90%) of the respondents in the area do not have the practices of feed conservation. This agrees with the report by Faye (2008) for Afar pastoralists. They enclose area around their home during the main rain season. However, they conserve browse species as a community to be used during dry season. They have local bylaws which prohibit giving by lopping browse trees to livestock when there is grass.

The total species richness was lower compared to the richeness recorded in larger Afromontane forests in central and southern highlands of Ethiopia. This was reflecting degradation of the forests. One reason for the degradation of these forests was the grazing and browsing effects from large number of livestock entering to the forest. Selective defoliation may affect species composition by lowering the ability of palatable or more morphologically-exposed species to produce seeds (Turner, 1999). Similarly, it was also found that animal density was a key management variable influencing plant species diversity and composition in arid and semiarid rangeland (Hiernaux, 1998).

Tigray, Desa'a Forest forest has a lower species density (number of species per unit area). This could be partly due to higher rainfall and less disturbance. One of these disturbances was from livestock. Accordingly, Desa'a Forest is less rich in species, especially in tree species, than many other Afromontane forests, e.g., Wof-Washa (Teketay, 1997), Jibat (Bekele, 1994), Harenna and Berhane-Kontir (Senbeta and Denich, 2006), peninsula of Zegie (Alelign et al., 2007), and Yayu (Gole et al., 2008).

Quantifying the proportion of the forage biomass allows useful comparisons of the productivity among species or management practices, and provides a basis for an appropriate stocking rate (Sollenberger and Cherney, 1995). According to Weber and Jelsch (2000), in semi-arid ecosystem, grass primary production of 800 kg/ha is considered to be poor, 1400 kg/ha is considered moderate and 3000 kg/ha is considered good. As these values were compared, the mean herbaceous biomass production determined by this study 1255.865 kg/ha was low. Therefore, browse species have immense contribution to fulfill this gap. This result was in line with the findings of Samson (2010) at Nechisar National Park. In general, biomass and range condition have similar trends by which higher forage production can be obtained from rangelands of good condition and the opposite holds true for rangelands in poor condition. This report agrees with the findings of Amsalu (2000); Abule (2005), and Ketema (2007).

The survey study result revealed that 55.6% of the respondents have tree inside their home compound or on their farm land and from these only 31.1% were planted by the farmers themselves. The effect of browsing in Desa'a Forest was reflected in the stunted growth of palatable species. Most of the species were dwarf. Only some of the total surveyed households practice forage development which was the key to overcome feed shortage and decreased the pressure from the forest. The adoption rates of forage species in the study area were very low. The major constraints of forages development voiced in Desa'a were free access to forest, lack of permanent settlement (migration), lack of awareness, seed, water, and land shortages. The current stocking rate in Desa'a Forest is at its maximum limit, which implies the need to control any further increases to avoid the effects of over grazing and browsing. These indicate high pressure on Desa'a Forest from livestock on browse species. This was due to low herbaceous biomass production in the forest. This study was conducted on Dessa'a Forest and peasant associations around the forest. Establishing a reference site for comparison would strengthen the results. Therefore, it is recommended that future studies focus on a reference site to compare the obtained results.

5. Conclusion

The study was conducted on Dessa'a forest and peasant associations around the forest. The main sources of income of the sampled households in the pastoralist areas were from the sale of livestock and their products. In addition to these, they got income from forest product and salt's sale. In the mixed farming system area, the main sources of household income were from the sale of live animals and their products. In addition, crop production and forest product sale has also been found to be one source of income for pastoralists (mixed farming) since livestock have been the main assets especially for the pastoralists in the study area upon which the livelihood of the pastoralists depend. The livestock species reared in the study area were included cattle, camels, goats, sheep and donkeys. Pastoralists reared dominantly cattle, camels and goats; while agro-pastoralists reared dominantly cattle in the study area. A large number of livestock entered to Desa'a Forest from the pastoralist area. They also used the grass and browse species inside the forest for the whole year. As the number of livestock and time they stay in the forest increases, the effect of browsing and grazing in the forest also increases. Both the pastoralists

and mixed farming system depend on Desa'a Forest for their livestock grazing and browsing. The available feed to livestock in the study area was grass, browse species. During dry season they mainly browse resources such as trees, bush and shrubs in Desa'a orest. In addition to these, crop reside, crop aftermath, and hay are also available in the mixed farming system.

The result of study showed that lopping the leaves and twigs of woody plants was the first measure taken by both mixed farming and pastoralists in the study area to solve the problem of feed shortage during the time of critical feed shortage. The livestock use Desa'a Forest on average for 8 months. Majority of the respondents entered their livestock into the forest. These indicate the dependence of the surrounding areas on Desa'a Forest for livestock feed. A total of 63 woody plant species were identified in the study area. According to the opinion of farmers and pastoralists in the study area 49.15%, 15.25%, 28.81%, and 6.79% of woody species identified are highly palatable, palatable, less palatable and unpalatable, respectively. The decreasing species from the forest according to the respondents were 'Amdug', 'Armedi', and Diospyros abyssinica. These species are very important sources of livestock feed. It is important to give attention to these species before they become endangered and extinct in the forest. The mean herbaceous biomass production determined by this study 1255.865 kg/ha was low. Therefore, browse species have immense contribution to fulfill this gap.

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